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The Effect of Proprioceptive and Balance Training on Recurrent Ankle Sprains in Individuals with Chronic Ankle Instability

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Abstract. Chronic ankle instability (CAI) is connected to recurrent ankle sprains, impaired proprioception, reduced postural control, and decreased functional stability. Proprioceptive and balance training are often used during rehabilitation, but differences in training methods and study populations makes the effectiveness difficult to determine. This research investigates the effect of proprioceptive and balance training on recurrent ankle sprains and functional stability in people with CAI. Evidence was examined from systematic reviews, meta-analyses, and randomized controlled trials focusing on recurrent ankle sprains, proprioception, balance, and ankle function. Findings show that proprioceptive training reduces recurrent ankle sprains, while balance training improves dynamic balance, proprioception, and functional ankle stability. However, limitations include differences in participant characteristics, training protocols, intervention duration, and outcome measures, so that findings cannot be generalized. Overall, proprioceptive and balancing training are useful for CAI rehabilitation, especially for improving dynamic balance and reducing recurrent ankle-sprain risk, although further specific research is required.

Keywords: Proprioception, recurrent ankle sprains, chronic ankle instability

1. Introduction

Ankle sprains are one of the most common musculoskeletal injuries, especially in sports that involve quick movements. A lateral ankle sprain is an injury involving one or more ligaments on the outside of the ankle. Commonly, it involves the anterior talofibular ligament (ATFL) and calcaneofibular ligament (CFL). Although ankle sprains might recover without proper rehabilitation and does not cause major complications, previous injuries are also an important risk factor for future sprains. Repeated ankle sprains can lead to Chronic Ankle Instability (CAI), and there is a feeling that the ankle is "giving away", and deficits in postural control and proprioception [1]. As it could reduce physical functions, this makes effective prevention strategies an important area of sports medicine research. Many athletes suffer from CAI, therefore proprioceptive and balancing training is needed.

Proprioceptive and balance training are mostly incorporated with rehabilitation and injury prevention programs. These trainings are effective as they challenge the sensory and neuromuscular systems that are in charge of maintenance of posture and ankle stability. By letting the patient to

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repeatedly finish control balancing challenges, training might result in improved proprioception, neuromuscular coordination, and functional stability, which in turn reduces the chance of recurrent sprains.

Previous research has shown improvements in balance and functional stability after proprioceptive and balancing training. At the same time, some studies also reported reductions in ankle sprains. However, different training protocols, participants, outcome measurements, and follow up periods make comparisons between different studies difficult. Furthermore, improvements in balance do not equal to a reduction in injury recurrence. Therefore, this research investigates to what extent proprioceptive and balance training reduces recurrent ankle sprains in individuals with chronic ankle instability by collecting data to examine recurrent injury rates and changes in balance and functional stability.

2. CAI and recurrent ankle sprains

2.1. What is chronic ankle instability (CAI)

Chronic ankle instability (CAI) refers to continuous functional problems and symptoms after an ankle sprain. There is a feeling that the ankle "giving away", which can involve both mechanical instability and functional instability. Mechanical instability happens when the ankle's ligament changes in structure and reduces the ability to restrict excessive joint movement. Conversely, functional instability involves impaired control of the joint during movement, which can occur after the ligament injury heals [2]. Therefore, CAI involves the consistent weakening of ankle stability and function.

2.2. Why do recurrent sprains occur

There are many factors contributing to recurrent ankle sprains in people with CAI. Ligament damage from the first sprain might reduce mechanical stability and its strength. Injuries might also affect proprioception, which decreases the ability to sense the position of a joint and can cause the ankle to feel less stable. Reduced postural control makes it difficult to remain stable when balance is interrupted and altered neuromuscular responses can reduce the speed and effectiveness of muscular reactions that stabilize the ankle. Moreover, muscle weakness weakens the ability of muscles to control the ankle's movement. These factors lead to impaired functional stability and increase the probability of ankle sprains. Research shows that approximately 46% of individuals who had ankle sprains suffer from CAI [3].

The relationship between these factors can be understood as a cycle. An initial ankle sprain damages the ligaments and disrupts proprioception and neuromuscular function, because these problems aren't fully resolved during recovery. Ankle instability is experienced by the individual and increases the probability of the next sprain, which can further damage structure and function of the ankle and further increase instability. Initial sprain → incomplete recovery and neuromuscular deficits → instability → recurrent sprain → greater instability. This shows the significance of effective rehabilitation as they could solve functional deficits after an ankle sprain, rather than simply focusing on recovering from the initial injury. This provides the basis for investigating if proprioception and balancing training can interrupt this cycle and reduce recurrent ankle sprains.

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3. Mechanisms of proprioceptive & balance training

3.1. Role of proprioception in ankle stability

As mentioned above, proprioception is the body's ability to detect the position, movement, and force of a joint by sensory information from receptors in muscles, tendons, ligaments, and joints. This information allow the nervous system to generate correct motor responses to maintain joint stability. After an ankle sprain, the damage to the ligament's structure and surrounding sensory receptors reduces the accuracy of proprioception, this limits the ability to notice changes in the ankle and the person can't effectively react to sudden movements. This impairment is especially noticeable in people with CAI, because it can lead to recurrent sprains.

3.2. Improvement of postural control and balance

Postural control is the ability to maintain the body in space while guaranteeing stability and orientation [4]. By doing so, three major systems are involved and work with each other, including the visual system, vestibular system, and proprioceptive system. Because of impaired proprioceptive responses and altered neuromuscular coordination, people with CAI show reduction in postural control, which increases the risk of losing balance during rapid movements.

Balance training result in improvements in postural control as proprioceptive training targets the repair and enhancement of and enhance the sensory function by continuously exposing the patient to movements that need high control and awareness of the ankle's position. Exercises such as single-leg standing, unstable surface training, and dynamic balance activities and force the sensors the process and help the nervous system to improve its detection and response to changes in the joint's position. By repeated exposure, proprioceptive training improves the accuracy and efficiency of the sensory feedback in ankle stabilization [5]. As a result, patients might be more capable of maintaining stability during rapid or unpredictable movements like landing or changing directions.

3.3. Neuromuscular adaptation and muscular control

Besides improving sensory feedback, proprioceptive and balance training also promotes neuromuscular control, which is an unconscious response of the muscles to training of muscles to dynamic joint stability stimuli [6]. Since CAI may reduce this control, exercises that challenge balance can activate the muscles around the ankle, especially the peroneal muscles. These muscles play a crucial role in preventing excessive inversion of the ankle joint. By repeating those practices, both muscle reaction time and coordination could be improved, allowing the ankle to respond more effectively during sudden changes in direction. This in turn reduces the risk of sprains.

3.4. Functional stability and injury prevention

These exercises can improve proprioception, postural control, and neuromuscular control, which provide better functional stability of the ankle. Functional stability is the ability of the ankle to control movements regardless of external or unpredictable forces. As functional stability is improved, the exposure to injury decreases because the individual will be able to stabilize the joint during dynamic movements. Therefore this shows that proprioception and balance training have the potential to interrupt the cycle of recurrent ankle sprains. Instead of only treating ligament damage from the initial injury, this exercises aim at the sensory and neuromuscular impairments contributing to continued instability. Therefore, this provides the theoretical basis for the investigation of whether

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these trainings can reduce recurrent ankle sprains and improve stability and performance of individuals with CAI.

4. Effectiveness in reducing recurrent ankle sprains

4.1. Improvements in proprioception

A systematic review included 3726 participants and seven randomized controlled trials, examining the effectiveness of proprioceptive training on reducing ankle sprain incidents [7]. Statistical data show that proprioceptive training significantly reduces the risk of repeated ankle sprains in people who have previously suffered ankle sprains, with a RR of 0.64 (95% CI: 0.51–0.81) [7].

A RR of 0.64 shows that the proprioceptive group has 64% risk compared to the controlled group, with a 36% relative reduction. At the same time, the confidence interval is under 1, indicating a positive effect of those trainings.

It is notable that the two studies have similar results. Another systematic review reported a RR of 0.63 while the meta-analysis showed a RR of 0.64. The consistency shows that the reduction in risk isn't likely to be caused by a single study alone.

4.2. Improvements of balancing training

At the same time, balance training also showed a positive effect in reducing risks. A systematic review and meta-analysis on intervention research on balancing training for competitive athletes was carried out. The analysis included 3577 athletes with five balance training studies. The study reported an RR of 0.54, meaning a 46% reduction in risk of ankle sprain compared with the control group [8].

There is a 6.5% difference, indicating a lower incidence of ankle sprains among athletes who completed balance training. The meta-analysis then proves that balance training can reduce ankle sprain risk. However, the participants had different injury histories, where some had previous ankle sprains and others hadn't. Therefore, the findings support the claim that balancing training is effective for the prevention but is not directly associated with individuals specifically diagnosed with CAI.

4.3. Reduction in recurrent ankle sprains

Evidence from proprioception and balance training indicates that these interventions can reduce the possibility of recurrence of ankle sprains. A systematic review reported a RR of 0.64 (95% CI: 0.51–0.81) for proprioceptive training, while another systematic review reported a lower RR of 0.54 for balance training. As both have RR lower than 1, the intervention groups experienced fewer ankle sprains than the control groups.

5. Effectiveness in improving balance & functional stability

5.1. Improvements in dynamic balance

Dynamic balance is important to ankle stability as it allows individuals to maintain control during movements. So this is particularly relevant to individuals with CAI because they have reduced control during single-leg activities.

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A systematic review and meta-analysis on 457 participants from 15 randomized controlled trials was tested. Compared with regular exercise, balancing training resulted in a significant improv in dynamic balance. There is an effect size of 0.83 (95% CI: 0.57–1.10), meaning that balancing training can greatly improve the ability to maintain stability during movements [9].

A study analyzed nine random controlled trials with 341 participants with CAI. Results show that balancing training improved Star Excursion Balance Test (SEBT) performance in the posteromedial direction (MD = 4.94, 95% CI: 1.88–8.00) and posterolateral direction (MD = 5.19, 95% CI: 1.57–8.81). This tells us that balancing training can largely improve dynamic posture control in individuals with CAI [10].

5.2. Improvements in static balance and postural control

Static balance is the ability to maintain stable when standing. In addition, deficits in postural control are present in individuals with CAI commonly. However, data from a meta-analysis showed that static balance has little improvement after balancing training. The study analyzed 48 randomized controlled trials with 1906 participants, while included 30 trials assessing postural balance. The meta-analysis stated that balancing training significantly improved dynamic balance (SMD = 0.77, 95% CI: 0.41–1.14), but showed no significant improvments in static balance compared to the controls. The certainty of evidence for this static-balance was very low to low, suggesting that the true effect might differ a lot from the observed results [11].

Therefore, current findings suggest balancing training has a strong effect on movement-based postural control, but small difference in stationary balance. This distinction indicates that improvements in functional stability might be more evident during dynamic activities than during static tasks.

5.3. Improvements in proprioception

Evidence and stats show that proprioceptive and balance-based rehabilitation can improve joint positioning sense of individuals with CAI. The systematic review and network meta analysis conducted 11 randomized controlled trials with 333 participants. Data suggests that foot and ankle muscle strengthening exercise improved proprioception the most (SURCA=74.6%), followed by static balance exercises (67.9%) and corrective exercises (56.1%). In comparison proprioceptive exercises had a lower improvement (49.6%), which suggests that strengthening and balancing training might also contribute to the restoring of proprioceptive function [12].

From a more recent stud, there were 24 randomized controlled trials involving 949 participants found that physical therapy significantly reduced ankle joint-position error (SMD = 0.66, 95% CI: 0.26–1.05) [13]. This suggests that rehabilitation improvs proprioceptive accuracy. In conclusion, the evidence supports the use of balance and strengthening exercise to improve proprioceptive function in individuals with CAI.

5.4. Improvements in functional ankle stability

Balance training can also improve functional ankle stability of individuals with CAI. A systematic review and meta-analysis analyzed nine randomized controlled trials with 341 participants. They found out that balancing training significantly improved CAI functional scores compared to the controls (MD = 3.95, 95% CI: 3.26–4.64, $p < 0.00001$), and improved in sports related function measured by the FAAM-Sports (MD = 17.74, 95% CI: 14.36–21.11, $p < 0.00001$) [10].

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Similarly, a meta-analysis analyzed 20 studies with 682 participants and reported a significant improvement in self reported ankle function following balancing training. (SMD = 1.02, 95% CI: 0.61–1.43, $p < 0.00001$). However, the heterogeneity was high ($I^2 = 72\%$), suggesting that difference between training programs might influence the results [14].

Overall, these findings suggest that balance training can improve the perceived ankle function and functional stability of CAI patients.

5.5. Reduction in recurrent ankle sprains

The significance of proprioceptive training in reducing recurrent ankle sprains can be evaluated by comparing the recurrent injuries between the intervention group and the control group. A randomized controlled trial carried out an experiment involving 522 athletes who experienced a lateral ankle sprain. Participants are randomly divided into 2 groups, usual care or usual care combined with a home based proprioceptive training program that lasts for 8 week. Within the one year follow up period, 56 of 256 participants (21.9%) in the training group experienced a recurrent ankle sprain, which is much lower than 89 of 266 participants (33.5%) in the control group [15].

There was an 11.6% difference in recurrence rate, indicating that the recurrence rate of ankle sprains in the training group was relatively lower. The study reported an adjusted relative risk (RR) of 0.63 (95% CI: 0.45–0.88), which means that the training group had about 37% lower risk of recurrent sprains compared to the control group after proprioceptive training. As the confidence interval is under 1, this reduction is statistically significant.

This strongly suggested that proprioceptive training can reduce recurrent ankle sprains. However, the participants were selected from a recent ankle sprain instead of a formal diagnosis of CAI. Therefore, the results are relevant to recurrent injuries but doesn't represent the people with CAI.

6. Factors affecting effectiveness & limitations of evidence

6.1. Training dosage and duration

The effectiveness of balancing training depends on the dosage and duration of the intervention. A meta-analysis discovered that training for 20-30 minutes per session, 3 times per week for 4-6 weeks improved ankle function and dynamic balance the most [14]. However, the study also stated that differences in training programs might also affect results. Therefore, although there's an optimal training dosage that can improve outcomes, there's insufficient evidence to shout that one program is optimal for all individuals with CAI.

Difference in exercise type also has different effectiveness. A systematic review and network meta-analysis found that strengthening training of the feet and ankle joints had the highest probability of improving proprioception (SUCRA = 74.6%), while proprioceptive exercises are much lower (49.6%) [12]. This suggests that combining different training methods can be more effective than relying on a single approach.

6.2. Heterogeneity and study limitations

The evidence is limited by difference between studies, which includes participant characteristics, exercise protocols, intervention duration and outcome measurements. A meta-analysis reported high heterogeneity for several outcomes, with I^2 values close to 84% for some SEBT measurements [14]. A meta-analysis reported a very low to low certainty for some balance outcomes [11]. Therefore,

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significant results should be interpreted cautiously as the effectiveness of training can vary between different people.

Another limitation is this research relies on secondary data, which is existing studies rather than primary experimental data. Some studies include participants with previous ankle sprains rather than diagnosed CAI, limiting the accessibility to the targeted population. Moreover, improvement in balance or functional stability do not equal to a long term reduction in recurrent sprains. Overall, the evidence supports that proprioceptive and balancing training, but difference between studies and limitations in evidence quality remain the effectiveness uncertain.

7. Conclusion

Overall, evidence suggest that proprioceptive and balancing training can reduce the risk of recurrent ankle sprains and improve functional stability in individuals with CAI. Studies investigating recurrent injuries reported lower injury rates after proprioceptive training, and evidence from balance training studies also showed an improvement in dynamic balance, proprioception, and ankle function. These findings support the proposed mechanism that improving sensory feedback, postal control and neuromuscular coordination can help deficits related to CAI.

However, the effectiveness of these results should not be considered as universal. Differences in training dosage, exercise type, participant characteristic, and outcome measurement varies between different studies. While some evidence states that they do nit necessarily show a long term reduction in recurrent sprains. Therefore, proprioceptive and balancing training is effective towards CAI rehabilitation, and they might benefit the most when combining those two types of trainings with other rehabilitation approaches. Further research using larger CAI-specific populations and longer follow-up periods would help establish the most effective training protocols for preventing recurrent ankle sprains.

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